

a) 25. (New) The fuel injector of claim 22, wherein the coating extends into the at least one discharge orifice.--.

Remarks

This Preliminary Amendment cancels without prejudice original claims 1 to 15 and new/substitute claims 1 to 9 in the underlying PCT Application No. PCT/DE00/02043, and adds without prejudice new claims 16 to 25. The new claims conform the claims to U.S. Patent and Trademark Office rules and do not add new matter to the application.

In accordance with 37 C.F.R. § 1.121(b)(3), the Substitute Specification (including the Abstract, but without the claims) contains no new matter. The amendments reflected in the Substitute Specification (including Abstract) are to conform the Specification and Abstract to U.S. Patent and Trademark Office rules or to correct informalities. As required by 37 C.F.R. § 1.121(b)(3)(iii) and § 1.125(b)(2), a Marked Up Version Of The Substitute Specification comparing the Specification of record and the Substitute Specification also accompanies this Preliminary Amendment. In the Marked Up Version, underlining indicates added text and bracketing indicated deleted text. Approval and entry of the Substitute Specification (including Abstract) is respectfully requested.

The underlying PCT Application No. PCT/DE00/02043 includes an International Search Report, dated November 13, 2000. The Search Report includes a list of documents that were uncovered in the underlying PCT Application. A copy of the Search Report accompanies this Preliminary Amendment.

The underlying PCT application also includes an International Preliminary Examination Report, dated September 24, 2001, and an annex (including new/substitute claims 1 to 9). An English translation of the International Preliminary Examination Report and the annex accompanies this Preliminary Amendment.

Applicants assert that the subject matter of the present application is new, non-obvious, and useful. Prompt consideration and allowance of the application are respectfully requested.

Dated: 1/2/2002

Respectfully Submitted,
KENYON & KENYON

By: Richard
Richard L. Mayer
(Reg. No. 22,490)

One Broadway
New York, NY 10004
(212) 425-7200

CUSTOMER NO. 26646

435000

FUEL INJECTOR

[Background Information

]

FIELD OF THE INVENTION

The present invention [is based on] relates to a fuel injector [according to the species defined in the main claim].

BACKGROUND INFORMATION

During motorized operation, in the case of direct injection of a fuel into the combustion chamber of an internal combustion engine, particularly with direct injection of gasoline or [the] injection of diesel fuel, [the] a problem [generally occurs] may occur; namely, that the downstream tip of the injectors projecting into the combustion chambers [is] may get coked by fuel deposits[,] (that is[to say], soot particles formed in the flame front may deposit on the valve tip). [That is why, for previously known] Thus, with injectors projecting into the combustion chamber, the danger of a negative influencing of the spray parameters ([e.g.] such as, for example, static flow amount, spray dispersal angle, drop size, skeining ability) may exist[s] over the[ir] service life of the injectors, which [can] may lead to disturbances in the running of the internal combustion engine[, up to the point of] and a failure of the injectors.

[Summary of the Invention

The] SUMMARY OF THE INVENTION

An exemplary fuel injector [of] according to the present invention [having the characterizing features of the Main Claim has] may have the advantage that [these aforesaid] the negative effects of the coking (soot deposit) on the valve tip projecting into the combustion chamber [are] may be reduced or

MARKED UP VERSION OF SUBSTITUTE SPECIFICATION

2L244S10201

eliminated. The application[, according to the present invention,] of coatings on the downstream valve end, [above all,] especially around the outlet areas of the discharge orifices, may reduce[s] or [prevents the]prevent coking or 5 formation of covering (soot) on the valve end [generally]that may negatively [influencing]influence the spray parameters and the valve function.

[Advantageous further developments and improvements of the 10 fuel injector indicated in the Main Claim are rendered possible by the measures specified in the dependent claims.

]

It [is]may be advantageous to apply layers on the valve end, by which either a catalytic conversion (burning) of the 15 deposits [is]may be effected[,] or the surface energy and/or the surface roughness of the component to be coated [is]may be reduced, a change in the wetting properties thereby being achieved, or the formation of a reaction layer thereby being prevented.

20

[Brief Description of the Drawing

An exemplary embodiment of]BRIEF DESCRIPTION OF THE DRAWINGS
Figure 1 shows an exemplary fuel injector according to the 25 present invention[is shown in simplified fashion in the Drawing, and is explained in detail in the following description. Figure 1 shows a fuel injector] inserted into a location bore of a cylinder head[;].

30 Figure 2 shows a longitudinal cross-section of an exemplary fuel injector [in]a[longitudinal section;]according to the present invention.

Figure 3 shows[a first exemplary embodiment of] a valve end 35 coated according to [the invention; Figure 4 shows a second]an exemplary embodiment of [a]the present invention.

Figure 4 shows another valve end coated according to an exemplary embodiment of the present invention[;].

5 Figure 5 shows an alternative guide and seat area on [the]a valve end at the spray-discharge side[;].

10 Figure 6 shows a longitudinal cross section of [a]an exemplary fuel injector according to the present invention for an auto-ignition internal combustion [engines; and]engine.

Figure 7 shows [the]an end of the fuel injector [according to]of Figure 6 on the combustion chamber side.

15 [Description of the Exemplary Embodiments

]DETAILED DESCRIPTION

20 Figure 1 shows a cut-off segment of a cylinder head 1 of an internal combustion engine, particularly a mixture-compressing internal combustion engine with externally supplied ignition[, in a cut-off segment]. Formed in cylinder head 1 is a graded location bore 2 [which]that extends symmetrically along a longitudinal axis 4 up to a combustion chamber 3. A fuel injector 5, according to an exemplary embodiment of the present invention, is inserted into location bore 2 of cylinder head 1. Fuel injector 5 [is]may be used for[the] 25 direct injection of fuel, particularly gasoline, but may also, for example, be used for injection of diesel, as [is]shown [with reference to]in Figures 6 and 7, into combustion chamber 3 of the internal combustion engine. Fuel injector 5 [is]may be actuated electromagnetically via an 30 electrical connecting cable 6. The fuel [is]may be supplied to fuel injector 5 [via]by an intake nipple 7. [F]The fuel injector 5 [shown in]of Figure 1 is a[so-called] top-feed injector, in which the fuel is guided in the axial direction from intake nipple 7 through entire injector 5, [it]the fuel 35 being ejected at end 8 on the spray-discharge side, opposite the end on the intake side, into combustion chamber 3.

To protect fuel injector 5 near [to]combustion chamber 3 from overheating, injector 5 [is]may be at least partially surrounded, for example, with a thermal-protection sleeve 9 [likewise]also inserted in location bore 2, [it also being 5 possible to dispense with]although the thermal-protection sleeve may be dispensed with.

Figure 2 shows a cross-section of an exemplary[embodiment of 10 a] fuel injector 5 according to the present invention[in a sectional view]. [It is a]An electromagnetically operable valve[that], which has a tubular, largely hollow-cylindrical core 11 [which]that is at least partially surrounded by a magnetic coil 10[and], is used as the internal pole of a magnetic circuit. [A, f]For example, a graded plastic coil form 13 receives a winding of magnetic coil 10 and, in conjunction with core 11 and a non-magnetic intermediate part 14 partially surrounded by magnetic coil 10, permits a particularly compact and short [design of the]injector in the area of magnetic coil 10. Instead of the electromagnetic 20 actuating element, fuel injector 5 may also be actuated in a piezoelectric or magnetostrictive manner.

Provided in core 11 is a traversing longitudinal opening 15, which extends along a longitudinal valve axis that coincides 25 with the longitudinal axis 4 of the location bore 2 of Figure 1. Core 11 of the magnetic circuit also serves as intake nipple 7. Fixedly joined to core 11 above magnetic coil 10 is an outer metallic ([e.g.]such as, for example, ferritic) 30 housing part 16 which, as an external pole or an outer conductive element, closes the magnetic circuit and completely surrounds magnetic coil 10, at least in the circumferential direction. Provided in the longitudinal opening 15 of core 11 on' the intake side is a fuel filter 17 [which]that filters out[those] fuel components [which]that, because of their 35 size, [could]may cause clogging or damage [in]to the injector.

Joined imperviously and fixedly to upper housing part 16 is a lower tubular housing part 18 which, for example, may enclose[s] or receive[s] an axially movable valve part [made of] including an armature 19, [as well as] a bar-shaped valve 5 needle 20 and an elongated valve-seat support 21[, respectively]. Both housing parts 16 and 18 [are] may be permanently joined to one another by, for example, a circumferential welded seam. The sealing between housing part 18 and valve-seat support 21 [is] may be effected, for example, 10 by a sealing ring 22. Valve-seat support 21 [has] includes, over its entire axial extension, an inner through hole 24 [which] that runs concentrically with respect to the longitudinal valve axis.

15 With its lower end, which [at the same time]also [represents] functions as the downstream termination of entire fuel injector 5, valve-seat support 21 surrounds a disk-shaped valve-seat element 26, fitted into through hole 24, [having] including a valve-seat surface 27 tapering 20 frustoconically downstream. Arranged in through hole 24 is valve needle 20, which has a valve-closure section 28 at its downstream end. This, for example, spherical, partially ball-shaped and conically tapering valve-closure section 28 cooperates[in known manner] with valve-seat surface 27 25 provided in valve-seat element 26. Downstream of valve-seat surface 27, at least one discharge orifice 32 for the fuel is introduced in valve-seat element 26.

30 [On the one hand, a]A guide opening 34 provided in valve-seat support 21 at the end facing armature 19[,] and[on the other hand,] a disk-shaped guide element 35 arranged upstream of valve-seat element 26 and [having] including a dimensionally accurate guide opening 36[,] are used for guiding valve needle 20 during its axial movement with armature 19 along the 35 longitudinal valve axis.

The lift of valve needle 20 [is] may be predefined by the installed position of valve-seat element 26. One end position of valve needle 20, when magnetic coil 10 is not energized, [is] may be established by the contact of valve-closure section 28 on valve-seat surface 27 of valve-seat element 26 [, while the other]. Another end position of valve needle 20, when magnetic coil 10 is energized, [is yielded] may be established by the contact of armature 19 on the downstream end face of core 11. The surfaces of the components in the [last-named] stop region [are] may be, for example, chromium-plated.

The electrical contacting of magnetic coil 10, and thus its excitation, [is] may be effected [via] by contact elements 43 which, outside of coil form 13, [are] may be provided with a plastic extrusion coat 44. Plastic extrusion coat 44 may also extend over further components ([e.g.] such as, for example, housing parts 16 and 18) of fuel injector 5. Leading out of plastic extrusion coat 44 is electrical connecting cable 6, [via] by which magnetic coil 1[is] 0 may be energized.

The guide and seat area provided in the end of valve-seat support 21 on the spray-discharge side[,] is formed in its through hole 24 by three axially sequential, disk-shaped, functionally-separate elements. Guide element 35, a swirl element 47 and valve-seat element 26 follow one another in the downstream direction. A compression spring 50 enclosing valve needle 20 secures [the three] guide element[s] 35, swirl element 47 and valve-seat element 26 in place in valve-seat support 21. Swirl element 47 may be produced inexpensively, for example, by stamping, wire EDM (electrical discharge machining), laser cutting, etching or other [known] methods from[a] sheet metal, or by electrodeposition. An inner swirl chamber and a plurality of swirl ducts opening[through] into the swirl chamber are provided in swirl element 47. In this way, before valve seat 27, a swirl component [is] may be impressed on the fuel to be ejected, so that the flow may

enter[s] with a swirl into discharge orifice 32, and a fine-swirled and well-atomized spray [is] may be delivered into combustion chamber 3.

5 During motorized operation, in the case of direct injection of a fuel into the combustion chamber of an internal combustion engine, the problem [generally] may occur[s] that the downstream tip of the injector projecting into the combustion chamber [is] may get coked by fuel deposits[,] (that is to 10 say, soot particles [formed] in the flame front may deposit on the valve tip). [That is why] Thus, for[previously known] injectors projecting into the combustion chamber, the danger of a negative influencing of the spray parameters ([e.g.] such as, for example, static flow amount, spray dispersal angle, drop size, skeining ability) exists over the[ir] service life of the injectors, which [can] may lead to disturbances in the running of the internal combustion engine, up to [the point of]a failure of the injectors.

20 According to an exemplary embodiment of the present invention, it is believed that these aforesaid problems [are] may be reduced or eliminated by applying coatings at valve end 8. In this context, different effects on surface 54 of the component to be coated, [e.g.] such as, for example, on valve-seat 25 element 26 made of Cr-steel, [are] may be attained by different coatings[; u]. Ultimately, however, [all] these measures are [aimed at reducing] intended to reduce or [preventing] prevent the coking or formation of covering (soot) on valve end 8, which may ha[s]ve a[generally] negative influence on the 30 spray parameters and the valve function. Individual coating possibilities are further described[in greater detail] in the following.

Catalytically acting layers [represent] may form a first group 35 of coatings. The electrolytically applied layers may provide for a catalytic conversion (burning) of the deposited soot

particles or prevent the deposit of carbon particles[from the start]. Suitable materials for such a coating to avoid coking [are]may be cobalt[and], nickel oxides and oxides of alloys of these metals[indicated]. The noble metals Ru, Rh, Pd, Os, 5 Ir and Pt, and alloys of these metals, among themselves or with other metals, may also exhibit catalytic effectiveness. The desired layers [are]may be produced, for example, by electrochemical or external-currentless metal deposition. In the case of Ni, Co or their alloys, oxide formation in air or 10 an additional oxidation step (using a wet chemical treatment, plasma) may also be used.

[The c]Coatings with which[the] wetting properties on corresponding surface 54 [are]may be changed, form a second large group of coatings. [Achieved by the] These coatings [in this case is that]may reduced the surface energy and/or the surface roughness of [the]critical regions at valve end 8[is/are reduced]. The interfacial energy between surface 54 and the fuel [is]may thereby be increased, which [means]causes the wetting to deteriorate[s]. In this way, the fuel drops at the regions coated according to an exemplary embodiment of the present invention [are]may be able to drip off and [are]may be entrained by the surrounding flow at valve end 8. Permanent wetting of valve end 8 may no longer take[s] place.

25 [Presenting themselves as s]Such layers [are]may be ceramic coatings, carbon coatings, which may be metal-containing or metal-free, or fluorine-containing coatings. The fluorine-containing coatings [are]may be, for example, heat-resistant PTFE-similar coatings or, in particular, 30 organic ceramic coatings or so-called Ormocer® coatings made of fluorosilicate (FAS). For example, such fluorine-containing coatings [are]may be applied by spraying or dipping. Sapphire coatings [are]may also [conceivable]be applied.

35 A third group [is formed by the]of coatings may be formed, with which a reaction layer [can]may be prevented. [Among

these are] Coatings for this third group may be, for example, nitrite layers (TiN, CrN) or oxide layers (tantalum oxide, titanium oxide). Similar to sputtering, for these layers, particles vaporized in a vacuum furnace [are] may be deposited on surfaces 54 to be coated.

[

] The regions to be coated at valve end 8 are, in particular, those [which] that immediately surround the at least one discharge orifice 32 in its outlet area 55[. Namely], since, a deposit of soot particles in discharge orifice 32 and/or at its immediate boundary edge may lead[s], in particular, to the disadvantageous influencing of the spray parameters ([e.g.] such as, for example, static flow quantity, spray dispersal angle, drop size, skeining ability) indicated above]. Thus[, in any case], a coating should be applied at the downstream end (outlet area 55) of each individual discharge orifice 32, regardless of on which component of fuel injector 5 discharge orifice[s] 32 [are] may be formed.

Figures 3 and 4 show bottom views of two exemplary embodiments of valve ends 8[,] coated according to an exemplary embodiment of the present invention[, i]. In [bottom views which differ in that, in one case] Figure 3, entire downstream component surface 54 of the component [having] including discharge orifice 32, [here] shown in Figure 3 as valve-seat element 26, is coated[(]. In Figure [3], and in the other case] 4, only an annular partial area of downstream component surface 54 is coated around the at least one discharge orifice 32[(Figure 4)].

] The dotted areas[are intended to clearly] show the coated regions. In Figures 3 and 4, outlet areas 55 of discharge orifices 32 lie in the drawing plane[. It should be emphasized that t] (not shown). The coatings may also extend slightly into discharge orifice 32.

In the exemplary embodiments [shown] of Figures 3 and 4, [in each case valve- seat] valve-seat element 26 is the component of fuel injector 5 [which] that forms downstream end 8 and has discharge orifice 32, so that the coating is[to be] applied at downstream end face 54 of valve-seat element 26. However, the application of a coating [according to the present invention] is not limited to a valve-seat element, but rather other valve components [which] that form downstream valve end 5 and thus project into combustion chamber 3 may also [have] include such a coating. For such components arranged downstream of valve seat 27 (see spray-discharge member 67 in Figure 5), as well, at least the regions immediately at discharge orifices 32 should be coated, so that the actual spray-discharge area [is] may be protected from coking.

Figure 5 shows an alternative guide and seat region at valve end 8 on the spray-discharge side, [in order] to [elucidate] show that [the assertions with respect to the] an exemplary coating [of] according to the present invention [are] may also be applicable to valve designs [which] that differ structurally. In th[is]e exemplary embodiment of Figure 5, a further disk-shaped spray-discharge member 67 is arranged downstream of valve-seat element 26. In this case, spray-discharge member 67 [has] includes discharge orifice 32. Discharge orifice 32 is inclined at an angle with respect to the longitudinal valve axis[,] and terminates downstream in a convexly curved spray-discharge region 66. Spray-discharge member 67 and valve-seat element 26 [are] may be permanently joined to one another by, for example, a welded seam 68 obtained by laser welding, the welding being carried out in an annular circumferential depression 69. In addition, spray-discharge member 67 [is] may be permanently joined to valve-seat support 21 by a welded seam 61. For example, the coating [is] may be applied[either] over entire curved spray-discharge region 66[,] or directly in a ring shape about outlet area 55 of discharge orifice 32, so that, relative to

the longitudinal valve axis, an off-center coating may exist[s] on[a] curved surface 54.

Figure 6 shows a longitudinal cross section through a fuel 5 injector for auto-ignition internal combustion engines, particularly diesel engines, only the part facing the combustion chamber being shown. An enlargement of the end of fuel injector 5 on the combustion chamber side shown in Figure 6 is shown in Figure 7. [A component constructed as v] Valve 10 member 72 is braced against a valve-retaining member 73 by a tension nut 75. Formed in valve member 72 is a bore 84, in which piston-shaped valve needle 20 is arranged[that], which is axially movable against a closing force. Bore 84 is implemented as a blind-end bore, the closed end of the bore 84 facing combustion chamber 3, forming a valve-seat surface 27 [which essentially] that has a truncated cone shape. Due to a bulge of the end of valve-seat surface 27 on the combustion chamber side, a blind hole 92 is formed, in whose wall at least one discharge orifice 90 is configured [connecting] that connects blind hole 92 to combustion chamber 3.

20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
105
110
115
120
125
130
135
140
145
150
155
160
165
170
175
180
185
190
195
200
205
210
215
220
225
230
235
240
245
250
255
260
265
270
275
280
285
290
295
300
305
310
315
320
325
330
335
340
345
350
355
360
365
370
375
380
385
390
395
400
405
410
415
420
425
430
435
440
445
450
455
460
465
470
475
480
485
490
495
500
505
510
515
520
525
530
535
540
545
550
555
560
565
570
575
580
585
590
595
600
605
610
615
620
625
630
635
640
645
650
655
660
665
670
675
680
685
690
695
700
705
710
715
720
725
730
735
740
745
750
755
760
765
770
775
780
785
790
795
800
805
810
815
820
825
830
835
840
845
850
855
860
865
870
875
880
885
890
895
900
905
910
915
920
925
930
935
940
945
950
955
960
965
970
975
980
985
990
995
1000
1005
1010
1015
1020
1025
1030
1035
1040
1045
1050
1055
1060
1065
1070
1075
1080
1085
1090
1095
1100
1105
1110
1115
1120
1125
1130
1135
1140
1145
1150
1155
1160
1165
1170
1175
1180
1185
1190
1195
1200
1205
1210
1215
1220
1225
1230
1235
1240
1245
1250
1255
1260
1265
1270
1275
1280
1285
1290
1295
1300
1305
1310
1315
1320
1325
1330
1335
1340
1345
1350
1355
1360
1365
1370
1375
1380
1385
1390
1395
1400
1405
1410
1415
1420
1425
1430
1435
1440
1445
1450
1455
1460
1465
1470
1475
1480
1485
1490
1495
1500
1505
1510
1515
1520
1525
1530
1535
1540
1545
1550
1555
1560
1565
1570
1575
1580
1585
1590
1595
1600
1605
1610
1615
1620
1625
1630
1635
1640
1645
1650
1655
1660
1665
1670
1675
1680
1685
1690
1695
1700
1705
1710
1715
1720
1725
1730
1735
1740
1745
1750
1755
1760
1765
1770
1775
1780
1785
1790
1795
1800
1805
1810
1815
1820
1825
1830
1835
1840
1845
1850
1855
1860
1865
1870
1875
1880
1885
1890
1895
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
2055
2060
2065
2070
2075
2080
2085
2090
2095
2100
2105
2110
2115
2120
2125
2130
2135
2140
2145
2150
2155
2160
2165
2170
2175
2180
2185
2190
2195
2200
2205
2210
2215
2220
2225
2230
2235
2240
2245
2250
2255
2260
2265
2270
2275
2280
2285
2290
2295
2300
2305
2310
2315
2320
2325
2330
2335
2340
2345
2350
2355
2360
2365
2370
2375
2380
2385
2390
2395
2400
2405
2410
2415
2420
2425
2430
2435
2440
2445
2450
2455
2460
2465
2470
2475
2480
2485
2490
2495
2500
2505
2510
2515
2520
2525
2530
2535
2540
2545
2550
2555
2560
2565
2570
2575
2580
2585
2590
2595
2600
2605
2610
2615
2620
2625
2630
2635
2640
2645
2650
2655
2660
2665
2670
2675
2680
2685
2690
2695
2700
2705
2710
2715
2720
2725
2730
2735
2740
2745
2750
2755
2760
2765
2770
2775
2780
2785
2790
2795
2800
2805
2810
2815
2820
2825
2830
2835
2840
2845
2850
2855
2860
2865
2870
2875
2880
2885
2890
2895
2900
2905
2910
2915
2920
2925
2930
2935
2940
2945
2950
2955
2960
2965
2970
2975
2980
2985
2990
2995
3000
3005
3010
3015
3020
3025
3030
3035
3040
3045
3050
3055
3060
3065
3070
3075
3080
3085
3090
3095
3100
3105
3110
3115
3120
3125
3130
3135
3140
3145
3150
3155
3160
3165
3170
3175
3180
3185
3190
3195
3200
3205
3210
3215
3220
3225
3230
3235
3240
3245
3250
3255
3260
3265
3270
3275
3280
3285
3290
3295
3300
3305
3310
3315
3320
3325
3330
3335
3340
3345
3350
3355
3360
3365
3370
3375
3380
3385
3390
3395
3400
3405
3410
3415
3420
3425
3430
3435
3440
3445
3450
3455
3460
3465
3470
3475
3480
3485
3490
3495
3500
3505
3510
3515
3520
3525
3530
3535
3540
3545
3550
3555
3560
3565
3570
3575
3580
3585
3590
3595
3600
3605
3610
3615
3620
3625
3630
3635
3640
3645
3650
3655
3660
3665
3670
3675
3680
3685
3690
3695
3700
3705
3710
3715
3720
3725
3730
3735
3740
3745
3750
3755
3760
3765
3770
3775
3780
3785
3790
3795
3800
3805
3810
3815
3820
3825
3830
3835
3840
3845
3850
3855
3860
3865
3870
3875
3880
3885
3890
3895
3900
3905
3910
3915
3920
3925
3930
3935
3940
3945
3950
3955
3960
3965
3970
3975
3980
3985
3990
3995
4000
4005
4010
4015
4020
4025
4030
4035
4040
4045
4050
4055
4060
4065
4070
4075
4080
4085
4090
4095
4100
4105
4110
4115
4120
4125
4130
4135
4140
4145
4150
4155
4160
4165
4170
4175
4180
4185
4190
4195
4200
4205
4210
4215
4220
4225
4230
4235
4240
4245
4250
4255
4260
4265
4270
4275
4280
4285
4290
4295
4300
4305
4310
4315
4320
4325
4330
4335
4340
4345
4350
4355
4360
4365
4370
4375
4380
4385
4390
4395
4400
4405
4410
4415
4420
4425
4430
4435
4440
4445
4450
4455
4460
4465
4470
4475
4480
4485
4490
4495
4500
4505
4510
4515
4520
4525
4530
4535
4540
4545
4550
4555
4560
4565
4570
4575
4580
4585
4590
4595
4600
4605
4610
4615
4620
4625
4630
4635
4640
4645
4650
4655
4660
4665
4670
4675
4680
4685
4690
4695
4700
4705
4710
4715
4720
4725
4730
4735
4740
4745
4750
4755
4760
4765
4770
4775
4780
4785
4790
4795
4800
4805
4810
4815
4820
4825
4830
4835
4840
4845
4850
4855
4860
4865
4870
4875
4880
4885
4890
4895
4900
4905
4910
4915
4920
4925
4930
4935
4940
4945
4950
4955
4960
4965
4970
4975
4980
4985
4990
4995
5000
5005
5010
5015
5020
5025
5030
5035
5040
5045
5050
5055
5060
5065
5070
5075
5080
5085
5090
5095
5100
5105
5110
5115
5120
5125
5130
5135
5140
5145
5150
5155
5160
5165
5170
5175
5180
5185
5190
5195
5200
5205
5210
5215
5220
5225
5230
5235
5240
5245
5250
5255
5260
5265
5270
5275
5280
5285
5290
5295
5300
5305
5310
5315
5320
5325
5330
5335
5340
5345
5350
5355
5360
5365
5370
5375
5380
5385
5390
5395
5400
5405
5410
5415
5420
5425
5430
5435
5440
5445
5450
5455
5460
5465
5470
5475
5480
5485
5490
5495
5500
5505
5510
5515
5520
5525
5530
5535
5540
5545
5550
5555
5560
5565
5570
5575
5580
5585
5590
5595
5600
5605
5610
5615
5620
5625
5630
5635
5640
5645
5650
5655
5660
5665
5670
5675
5680
5685
5690
5695
5700
5705
5710
5715
5720
5725
5730
5735
5740
5745
5750
5755
5760
5765
5770
5775
5780
5785
5790
5795
5800
5805
5810
5815
5820
5825
5830
5835
5840
5845
5850
5855
5860
5865
5870
5875
5880
5885
5890
5895
5900
5905
5910
5915
5920
5925
5930
5935
5940
5945
5950
5955
5960
5965
5970
5975
5980
5985
5990
5995
6000
6005
6010
6015
6020
6025
6030
6035
6040
6045
6050
6055
6060
6065
6070
6075
6080
6085
6090
6095
6100
6105
6110
6115
6120
6125
6130
6135
6140
6145
6150
6155
6160
6165
6170
6175
6180
6185
6190
6195
6200
6205
6210
6215
6220
6225
6230
6235
6240
6245
6250
6255
6260
6265
6270
6275
6280
6285
6290
6295
6300
6305
6310
6315
6320
6325
6330
6335
6340
6345
6350
6355
6360
6365
6370
6375
6380
6385
6390
6395
6400
6405
6410
6415
6420
6425
6430
6435
6440
6445
6450
6455
6460
6465
6470
6475
6480
6485
6490
6495
6500
6505
6510
6515
6520
6525
6530
6535
6540
6545
6550
6555
6560
6565
6570
6575
6580
6585
6590
6595
6600
6605
6610
6615
6620
6625
6630
6635
6640
6645
6650
6655
6660
6665
6670
6675
6680
6685
6690
6695
6700
6705
6710
6715
6720
6725
6730
6735
6740
6745
6750
6755
6760
6765
6770
6775
6780
6785
6790
6795
6800
6805
6810
6815
6820
6825
6830
6835
6840
6845
6850
6855
6860
6865
6870
6875
6880
6885
6890
6895
6900
6905
6910
6915
6920
6925
6930
6935
6940
6945
6950
6955
6960
6965
6970
6975
6980
6985
6990
6995
7000
7005
7010
7015
7020
7025
7030
7035
7040
7045
7050
7055
7060
7065
7070
7075
7080
7085
7090
7095
7100
7105
7110
7115
7120
7125
7130
7135
7140
7145
7150
7155
7160
7165
7170
7175
7180
7185
7190
7195
7200
7205
7210
7215
7220
7225
7230
7235
7240
7245
7250
7255
7260
7265
7270
7275
7280
7285
7290
7295
7300
7305
7310
7315
7320
7325
7330
7335
7340
7345
7350
7355
7360
7365
7370
7375
7380
7385
7390
7395
7400
7405
7410
7415
7420
7425
7430
7435
7440
7445
7450
7455
7460
7465
7470
7475
7480
7485
7490
7495
7500
7505
7510
7515
7520
7525
7530
7535
7540
7545
7550
7555
7560
7565
7570
7575
7580
7585
7590
7595
7600
7605
7610
7615
7620
7625
7630
7635
7640
7645
7650
7655
7660
7665
7670
7675
7680
7685
7690
7695
7700
7705
7710
7715
7720
7725
7730
7735
7740
7745
7750
7755
7760
7765
7770
7775
7780
7785
7790
7795
7800
7805
7810
7815
7820
7825
7830
7835
7840
7845
7850
7855
7860
7865
7870
7875
7880
7885
7890
7895
7900
7905
7910
7915
7920
7925
7930
7935
7940
7945
7950
7955
7960
7965
7970
7975
7980
7985
7990
7995
8000
8005
8010
8015
8020
8025
8030
8035
8040
8045
8050
8055
8060
8065
8070
8075
8080
8085
8090
8095
8100
8105
8110
8115
8120
8125
8130
8135
8140
8145
8150
8155
8160
8165
8170
8175
8180
8185
8190
8195
8200
8205
8210
8215
8220
8225
8230
8235
8240
8245
8250
8255
8260
8265
8270
8275
8280
8285
8290
8295
8300
8305
8310
8315
8320
8325
8330
8335
8340
8345
8350
8355
8360
8365
8370
8375
8380
8385
8390
8395
8400
8405
8410
8415
8420
8425
8430
8435
8440
8445
8450
8455
8460
8465
8470
8475
8480
8485
8490
8495
8500
8505
8510
8515
8520
8525
8530
8535
8540
8545
8550
8555
8560
8565
8570
8575
8580
8585
8590
8595
8600
8605
8610
8615
8620
8625
8630
8635
8640
8645
8650
8655
8660
8665
8670
8675
8680
8685
8690
8695
8700
8705
8710
8715
8720
8725
8730
8735
8740
8745
8750
8755
8760
8765
8770
8775
8780
8785
8790
8795
8800
8805
8810
8815
8820
8825
8830
8835
8840
8845
8850
8855
8860
8865
8870
8875
8880
8885
8890
8895
8900
8905
8910
8915
8920
8925
8930
8935
8940
8945
8950
8955
8960
8965
8970
8975
8980
8985
8990
8995
9000
9005
9010
9015
9020
9025
9030
9035
9040
9045
9050
9055
9060
9065
9070
9075
9080
9085
9090
9095
9100
9105
9110
9115
9120
9125
9130
9135
9140
9145
9150
9155
9160
9165
9170
9175
9180
9185
9190
9195
9200
9205
9210
9215
9220
9225
9230
9235
9240
9245
9250
9255
9260
9265
9270
9275
9280
9285
9290
9295
9300
9305
9310
9315
9320
9325
9330
9335
9340
9345
9350
9355
936

contrary to the closing force operating on valve needle 20, and thus, given suitable fuel pressure, valve needle 20 [is] may be able to move against the closing force.

5 Formed on valve needle 20 at the end on the combustion chamber side is a valve-sealing surface 88, forming valve-closure section 28 (not shown in Figure 6 or Figure 7), which cooperates with [valve- seat] valve-seat surface 27 [in such a way] so that the at least one discharge orifice 90 is sealed 10 against pressure space 86 by the contact of valve-sealing surface 88 on valve-seat surface 27. Due to the opening lift movement directed inwardly away from combustion chamber 3, valve-sealing surface 88 lifts off of valve-seat surface 27 and connects pressure space 86 to discharge orifice 90.

15 The catalytically active coating [is] may be applied, for example, over the entire end face of valve member 72 facing combustion chamber 3. [It is also possible to provide] Further, only curved outer surface 96 of blind hole wall 93 may be provided, which borders blind hole 92 and in which the at least one discharge orifice 90 is formed, with a coating. Provision may also be made to continue the coating into 20 discharge orifice 90.

[Abstract]

ABSTRACT OF THE DISCLOSURE

[The present invention relates to a]A fuel injector[(5)], particularly a fuel injector projecting directly into a combustion chamber of an internal combustion engine, [having] including one fuel inlet[(7)], [having] an energizable actuating element[(10), [11, 19)] by which a valve-closure member [(28)] is able to be moved, [having] one fixed valve seat[(27)], with which the valve-closure member[(28)] cooperates for opening and closing the valve, and [having] one fuel outlet formed in a downstream valve end[(8)], the fuel outlet being formed by at least one discharge orifice [(32)] arranged downstream of the valve seat[(27)]. The valve-seat element [(26) having] includes at least one discharge orifice [(32)] has on its downstream end face[(54)], at least in an outlet area[(55)] of the discharge orifice[(32)], a coating [which] to prevent[s] coking in this region.

436279